

Effect of soil–structure interaction on seismic performance-based design of concrete structures

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My reasons and purposes for undertaking this project

When simulating an earthquake, the structure should not only be tested using records registering in the free field of soil. The dynamic response of a structure during an earthquake depends on the type of soil foundation. A realistic estimate of the effect of an earthquake on a structure cannot be made without this. Soil type, soil layer and changes in the depth of the layer are factors affecting the seismic behavior of structures that have been considered in the analysis of structures. It can be said that soil-structure interaction produces behavior that is closer to actual behavior. After considering a soft soil substructure, structures assumed to have a rigid connection to the soil will show softer behavior. Soil damping will increase all the damping of the system, but further review of the factors affecting the performance of a structure should be done [1].

The shift of functional design has been from the force method to design. After structural analysis and estimation of internal forces of members and deformation caused by gravity loads and lateral loads of an earthquake, the performance of structural components will be examined according to accepted criteria. In original and non-original members controlled by deformation, non-linear deformation analysis is beyond capacity. For this purpose, member deformation capacity should meet the proposed regulations by considering all simultaneous effects to a member [2].

To define the performance of a specified structure, it is necessary to identify the acceptable extent of damage of the earthquake. ATC40 and, FEMA 273 define three levels of structural performance as follows:

- Immediate occupancy: Structural damage after an earthquake is negligible and the vertical and lateral load-bearing structural systems maintain almost all properties existing before the earthquake.
- Life safety: Significant damage occurs to the structure but there is still a safety margin before considering the structure unstable. Structural and non-structural members will not fall.
- Structural stability or collapse prevention: Structural damage has reached the point at which the structures have not yet reached the stage of complete collapse and retain vertical stability.

The interaction of soil and foundation is the most important parameter influencing the level of expected performance of structures. The soil type and the substrate and the type of foundation of the substructure and the interaction between them causes a change in shift of the structures without interaction. A change in displacement can be expected to change the operating conditions of the original members and the overall performance of the structures [3].

My research project

In this study, the effect of soil-structure interaction on the performance of a structure will be evaluated according to performance-based design of concrete structures. The main objective of this study is to evaluate the effect of soil-structure interaction on the expected performance of structures and detect possible changes in the level of performance of concrete structures with regard to soil-structure interaction.

To consider the interaction of soil and structures, the conical model will be used as a substructure method. In the conical model, the soil under the foundation is modeled as a divergent cone and displacement in the soil is applied through the massless and rigid foundation. According to type of displacement of soil, the conical model uses the rotational springs model to model the rotational movement, including circular and torsional motion. The transitional springs will be modeled in order to model vertical and horizontal displacement.

The level of expected performance for structures is based on FEMA 356. In order to consider the effect of foundation type on the structure, three different foundations will be considered:

1. A structure with a solid foundation;
2. A structure with a shallow foundation for soil of average quality;
3. A structure having a foundation with piles for loose soil.

Structural concrete structures examined in this study will be from the middle and upper classes. The system assumed for lateral structures moment frame system will be an average double bending frame with shear walls. This project will evaluate the influence the classes and lateral systems on the performance of structures.

Research Aims

1. To study the level of performance of the concrete structures considering soil-structure interaction;
2. To study the effect of the fundamnet on foundation interaction with the soil and its effect on structural performance;
3. To study the effect of soil-structure interaction for different levels of earthquake according to the levels of the structures.

Questions for research may include the following:

1. Will soil-structure interaction negatively affect performance?

2. Will soil-structure interaction have a greater effect on the performance of the main components of structures or on non-original members?
3. Will the class and lateral system effect the level structural performance?

Methodology

There are two methods for evaluating the dynamic response of structures with regard to soil-structure interaction. In the first method, the free-field soil record in the soil is corrected and then the structure is analyzed under the modified record. In the second method, the soil is considered along with the structure. In this method, the structure and soil are used in a model that considers the effect of soil.

Methods that use free-field motion can be divided into direct and substructure methods. In the direct method, the soil and structure are modeled together and analysis is done in one step. Soil is often modeled by using solid finite elements and the structure using beam finite elements. The boundary of interaction is nearest to the contact area of the environment and structures. In this case, the stiffness of the soil around the structure is considered part of the soil. Because the theory of superposition of forces is not required, nonlinear analysis can be used.

In the substructure method (indirect method), the interaction boundary is in contact with the environment and structures. This border should be very accurate and indicates the soil stiffness of structures and the semi-infinite environment condition for the direction of wave propagation. The soil and structure are independently modeled and then the entire model is analyzed. In order to model the soil, springs and dampers are used that have properties that are dependent on excitation frequency [4].

This study takes into account soil-structure interaction using a cone model as a structural method. In the cone model, the soil under the foundation is modeled as a divergent cone and displacement of soil is applied throughout the massless and rigid fundamnet. Due to the relocation of soil, the cone model will be modeled using rotational springs to model rotational displacement that includes a cradle circular motion. The torsional and transitional springs will be modeled by considering the vertical and horizontal displacement.

In this project, tall concrete buildings having 10, 15 and 20-story plans will be modeled in OpenSees nonlinear software. For each of these structures, two types of bending system will be modeled (lateral bending frame and shear walls with a bending frame) for three types of fundamnet.

References

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